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# Effect of somatic cell count in goat milk on yield, sensory quality, and fatty acid profile of semisoft cheese

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## ABSTRACT

This study investigated the effect of somatic cell count (SCC) in goat milk on yield, free fatty acid (FFA) profile, and sensory quality of semisoft cheese. Sixty Alpine goats without evidence of clinical mastitis were assigned to 3 groups with milk SCC level of <500,000 (low), 500,000 to 1,000,000 (medium), and 1,000,000 to 1,500,000 (high) cells/mL. Thirty kilograms of goat milk with mean SCC levels of 410,000 (low), 770,000 (medium), and 1,250,000 (high) cells/mL was obtained for the manufacture of semisoft cheese for 2 consecutive weeks in 3 lactation stages. The composition of milk was analyzed and cheese yield was recorded on d 1. Cheese samples on d 1, 60, and 120 were analyzed for total sensory scores, flavor, and body and texture by a panel of 3 expert judges and were also analyzed for FFA. Results indicated that milk composition did not change when milk SCC varied from 214,000 to 1,450,000 cells/mL. Milk with higher SCC had a lower standard plate count, whereas coliform count and psychrotrophic bacteria count were not affected. However, milk components (fat, protein, lactose, casein, and total solids) among the 3 groups were similar. As a result, no significant differences in the yield of semisoft goat cheeses were detected. However, total sensory scores and body and texture scores for cheeses made from the high SCC milk were lower than those for cheeses made from the low and medium SCC milks. The difference in milk SCC levels also resulted in diverse changes in cheese texture (hardness, springiness, and so on) and FFA profiles. Individual and total FFA increased significantly during ripening, regardless the SCC levels. It is concluded that SCC in goat milk did not affect the yield of semisoft cheese but did result in inferior sensory quality of aged cheeses.

**Key words:** somatic cell count, goat cheese, sensory quality, free fatty acid

## INTRODUCTION

The worldwide dairy goat population reached 160 million in 2006 and goat milk production surpassed 13.8 million tonnes, representing significant increases of 12 and 15%, respectively, as compared with a decade ago (FAOSTAT, 2007). Since goat milk was specifically defined in the Grade A Pasteurized Milk Ordinance in 1989, it has become more and more popular in the United States. The number of dairy goats in the United States approached 2 million in 2007 (USDA, 2007). Goat milk cheese has gradually gained popularity among certain ethnic groups, health food lovers, and goat milk producers in the United States. The dairy goat industry is now playing an active role in the agricultural economy of many states and becoming an economically viable income source for many small-scale farmers (Park, 1991; Dubeuf et al., 2004).

Subclinical mastitis in goats has been reported to reduce milk and cheese yields because of deterioration of milk quality in the infected glands, reflected by high SCC (Leitner et al., 2004). Somatic cell count in cow milk is commonly used as an effective index of udder health in dairy cows. Many studies have been carried out to determine the effect of SCC on the yield and quality of milk and dairy products, especially cheeses. The increase of cow milk SCC above 100,000 cells/mL was reported to have a negative effect on cheese yield (Barbano et al., 1991). High SCC in milk results in a longer coagulation time and a weaker coagulum during cheesemaking, which in turn leads to increased moisture content in the cheese and an overall lower cheese yield (Rogers and Mitchell, 1994; Auldist and Hubble, 1998; Klei et al., 1998).

It is generally agreed that goat milk has a higher SCC than cow milk and sheep milk (Park, 1991; Zeng and Escobar, 1996) because of the apocrine secretory system of dairy goats (Dulin et al., 1982). Goat milk SCC has been the target of different legal limits or payment-by-

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quality schemes proposed by different countries (Zeng et al., 2010). The current Pasteurized Milk Ordinance regulation (PMO, 2007) allows 1,000,000 somatic cells/mL in grade A goat milk, whereas the limit of cow milk SCC has been 750,000 cells/mL. However, the interrelationship between intramammary infection, inflammatory response, caseinolysis, and consequently, cheese yield and quality are complicated (Le Roux et al., 1995). To interpret the effects of subclinical mastitis in goats on quality and production of milk and cheese, and to determine whether SCC can be used as a single, reliable measure to correlate between SCC in goat milk and cheese yield and quality, it is necessary to understand the effects of SCC levels in goat milk on the yield and quality of cheese. Information is also greatly needed to assist payment-by-quality schemes to make goat dairying profitable for both goat milk producers and cheese manufacturers and to promote the dairy goat industry as an economically sustainable agricultural segment. Therefore, this study was carried out to investigate the effect of SCC in goat milk on yield, quality, and fatty acid profile of semisoft cheese.

## MATERIALS AND METHODS

### *Milk Sample Collection*

Milk was obtained from lactating Alpine does in the E (Kika) de la Garza American Institute for Goat Research of Langston University (Langston, OK) at 3 stages of lactation (May, July, and early October). Average DIM were approximately 35, 110, and 181 d for early, middle, and late lactations, respectively. Prior to milk collection, milk samples from individual lactating goats were screened 3 times for SCC at the certified Langston University DHI laboratory. Sixty Alpine goats without evidence of clinical mastitis were assigned to 3 groups with milk SCC levels of <500,000 (low), 500,000 to 1,000,000 (medium), and 1,000,000 to 1,500,000 (high) cells/mL. Does in each group were milked separately using 10 units of a side-by-side pipeline milking system (Alfa Laval Agri Inc., Kansas City, MO) on the Langston University dairy goat farm. Thirty kilograms of milk per batch was collected from each group in 2 to 3 milkings for cheese manufacture. Duplicate experiments were conducted in 2 consecutive weeks at all 3 stages of lactation.

### *Chemical Composition, SCC Analysis, and Microbiological Tests*

Prior to cheesemaking, 1 representative milk sample (40 mL) from each group was collected and analyzed in duplicate for chemical composition (fat, total protein, lactose, and TS) and SCC using a CombiFoss 5000 unit (Foss North America, Eden Prairie, MN) that was calibrated monthly. Antibiotic residue was also tested using SNAP test kits and a Snapshot Reader (Idexx Laboratories Inc., Westbrook, ME) before cheese manufacture. Another representative milk sample (100 mL) was aseptically collected from the storage milk can of each group and analyzed for SPC, coliform count (**CC**), and psychrotrophic bacteria count (**PBC**; Wehr and Frank, 2004) on the same day. After microbiological tests, pH of goat milk was measured (Wehr and Frank, 2004).

### *Cheese Manufacture and Sampling*

Three batches of semisoft (Colby-like) cheese were made simultaneously in the Langston University dairy processing pilot plant from milk with 3 SCC levels following procedures of Kosikowski and Mistry (1999). Briefly, 30 kg of milk was pasteurized at 63°C for 30 min and cooled to the ripening temperature (31 ± 1°C). Three grams of direct vat set (DVS) culture (MAO11, Texel Group Rhone-Poulenc, Saint-Romain, France) was inoculated to the milk. After 60 min of ripening, 5 mL of double-strength chymosin (Rhodia Inc., Madison, WI) was diluted with deionized water (1:40) and added to the milk. After 45 min of coagulation at 31 ± 1°C, the coagulum was cut with 8-mm curd knives. The curd temperature was raised to the cooking temperature of 39°C over a period of 30 min, and the curd was cooked for another 30 min at this temperature. One-third of the whey was drained and the curd was washed twice using cold water. After draining, 130 g of salt was sprayed onto and mixed with the curd. The curd was packed into hoops and initially pressed at 276 kPa for 2 h, and then at 483 kPa for 14 h (overnight) at room temperature (21 ± 1°C). Cheeses were taken out of the hoops and cut into 3 blocks after weighing. One of the blocks was used for subsequent sampling and analysis of pH, sensory quality, and texture profile analysis (**TPA**). Two more samples of the same block were collected and stored at −20°C for later analyses of moisture and FFA. The other 2 cheese blocks were aged at 8 to 10°C for 60 and 120 d after vacuum package. Cheese samples were then collected and the same analyses were conducted on d 60 and 120 of aging. The above study was repeated the following week at all 3 stages of lactation.

### *Cheese Composition*

Moisture content of cheese samples was determined by freeze-drying (FTS Systems, Stone Ridge, NY). Then, moisture-adjusted cheese yields ($Y_{MA}$) were arithmetically calculated from actual yields ($Y_A$) as described by

Zeng et al. (2007) for statistical analysis based on the formula $Y_{MA} = Y_A \times (100 - \text{moisture})/(100 - \text{average moisture})$. Cheese yield in DM ($Y_{DM}$) was calculated as $Y_{DM} = Y_A \times (100 - \text{moisture})/100$ (Fenelon and Guinee, 1999). Fat content was determined using a supercritical fluid extraction system (Isco Inc., Lincoln, NE). Crude protein content was measured using an Industrial Method N334–74 WB (Technicon Autoanalyzer II, Bran+Luebbe, Buffalo Grove, IL). Cheese pH was directly measured with cheese slurry using an Accumet AP61 portable pH meter (Fisher Scientific, Houston, TX).

### TPA and Sensory Evaluation

Cheese blocks were warmed to room temperature (21 ± 1°C) for 30 min before sampling. Cylindrical samples were taken with a cork borer (#9, 15-mm diameter) and cut into the same height (3 cm). Five representative samples were taken from 1 subblock and texture profiles were determined with a TPA procedure using an Instron texture analyzer (Model 5500, Instron Corporation, Canton, MA). The cross-head speed was 5 cm/min, chart recorder speed was 10 cm/min, and deformation was 75% of original sample height. From typical force deformation curves obtained, texture variables (hardness, springiness, cohesiveness, and adhesiveness) were calculated using TPA software.

At the same time of TPA test, cheese samples (1, 60, or 120 d of age) were also collected in duplicate for the evaluation of sensory quality by a panel of 3 expert judges on a 15-point scale (15 being a perfect cheese), with 10 points designated to flavor and 5 points to body and texture (Bodyfelt et al., 1988). The flavor attributes were acid, bitter, unclean, rancid, lacks flavor, salty, and too goaty, whereas the body and texture attributes included coarse, crumbly, grainy, pasty, and weak.

### FFA Profile

Approximately 1 g of freeze-dried (Dura-Stop Tray Dryer, FTS Systems Inc., Stone Ridge, NY) goat milk cheese was used for fat extraction following the method of Deeth et al. (1983). Free fatty acids were separated and identified by gas chromatography using a HP6890 unit with a flame ionization detector and an HP-INNOWax 19091N-133 polyethylene glycol column (30 m × 0.25 mm × 0.25 μm i.d., Agilent Technologies, Wilmington, DE). The column oven temperature was held at 60°C for 2 min, and then increased at a rate of 6°C/min to a final temperature of 210°C, followed by a 2-min hold. Injector and detector temperatures were 250°C, and the injector port had a 50:1 split ratio. Flow-rates were 20 mL/min for the nitrogen carrier gas (31 kPa pressure), 450 mL/min for air, 40 mL/min for hydrogen, and 45 mL/min for nitrogen as the make-up gas. Integration for each fatty acid was performed using Hewlett-Packard HP6890-Chemstation Software (Agilent Technologies). Peaks were identified based on retention times for standards of individual fatty acids. Final FFA concentrations were expressed on fat basis (mg/g of fat).

### Statistical Analysis

This study was conducted following the model $Y_i = \mu + S_i + A_j + e_{ij}$, where $Y_i$ = dependent variable; $\mu$ = overall mean; $S_i$ = SCC levels, i = low, medium, high; $A_j$ = aging stage, j = d 1, 60, 120; and $e_{ij}$ = error term. The independent variables were SCC levels and aging stage, whereas the dependent variables were milk and cheese composition and cheese TPA, FFA, and sensory scores. Data were statistically analyzed using GLM mixed models of SAS (SAS Institute, 2005). The average of each variable was used for mean comparison (i.e., duplicates for milk and cheese composition, 5 repeats of each cheese for TPA, duplicates for FFA, and triplicates for sensory scores). If there were significant effects of SCC levels, lactation stage, aging stage, and interactions between SCC levels and lactation stage or aging stage, the least significant difference was used for mean comparisons, with significance level of 0.05.

## RESULTS AND DISCUSSION

### Effect of SCC on Composition and Microbiological Quality of Goat Milk

The composition and microbiological quality of goat milk with different SCC are shown in Table 1. The actual SCC in cheese milk were in a range of 214,000 to 1,450,000 cells/mL, and the average SCC of the 3 groups of cheese milk were 408,000 ± 114,000 (low), 764,000 ± 114,000 (medium), and 1,246,000 ± 203,000 (high) cells/mL in the present study. The SCC in goat milk may be affected by various factors such as lactation, estrus, milking, and so on (Haenlein, 2002). The predication of goat udder half infection by SCC is unreliable and even with high milk SCC goat udders may show absence of mastitis conditions. Zeng and Escobar (1995) reported that no histological and pathological differences in the mammary glands or other evidence of mastitis were detected on fresh udder half tissues of goats with low (950,000 cells/mL), medium (1,500,000 cells/mL), and high (3,300,000 cells/mL) SCC. In the present study, the difference of SCC was not expected

**Table 1.** Composition and microbiological quality of goat milk with different SCC levels[1]

| Item | Low | Medium | High | SEM |
|---|---|---|---|---|
| SCC ($10^3$/mL) | 408[c] | 764[b] | 1,246[a] | 61.81 |
| pH | 6.77 | 6.76 | 6.78 | 0.01 |
| Composition | | | | |
| Fat (%) | 2.67 | 2.62 | 2.57 | 0.06 |
| Protein (%) | 2.52 | 2.49 | 2.50 | 0.06 |
| TS (%) | 10.26 | 10.20 | 10.15 | 0.10 |
| Lactose (%) | 4.20 | 4.21 | 4.19 | 0.04 |
| CN (%) | 1.99 | 1.97 | 1.98 | 0.05 |
| Protein:fat ratio | 0.95 | 0.97 | 0.99 | 0.06 |
| CN:protein ratio | 0.79 | 0.79 | 0.79 | 0.00 |
| CN:fat ratio | 0.75 | 0.764 | 0.78 | 0.03 |
| Microbiology[2] | | | | |
| CC (log cfu/mL) | 2.58 | 2.61 | 2.42 | 0.13 |
| SPC (log cfu/mL) | 4.11[ab] | 4.21[a] | 3.65[b] | 0.25 |
| PBC (log cfu/mL) | 2.91 | 3.20 | 2.89 | 0.22 |

[a–c]Means (n = 12; 2 × 3 × 2) in the same row with different letters differ ($P < 0.05$) according to LSD.

[1]SCC levels: low = <500,000 cells/mL; medium = 500,000–1,000,000 cells/mL; high = 1,000,000–1,500,000 cells/mL.

[2]CC = coliform count; PBC = psychrotrophic bacteria count.

to be induced by clinical mastitis. Klei et al. (1998) reported that pH of cow milk with high SCC level induced by *Streptococcus agalactiae* infusion was higher than that of regular cow milk with a low SCC level. Vivar-Quintana et al. (2006) reported similar results in sheep milk. However, no significant differences in pH of goat milk were found between different SCC levels in the present study. This observation indicated that the higher SCC level in goat milk, if not induced by evident intramammary infection, might not result in change of goat milk pH. Somatic cell count did not affect the fat, protein, and TS contents of goat milk ($P > 0.05$); however, other studies have demonstrated that milk of a high SCC level had higher (Mitchell et al., 1986) or lower (Jaeggi et al., 2003) fat content. Ying et al. (2002) showed goat milk protein content had a positive correlation to SCC, whereas Jaeggi et al. (2003) reported that sheep milk with high SCC (>1,000,000 cells/mL) had lower protein and TS contents than milk with low SCC (<1,000,000 cells/mL). The different results of SCC effect on milk composition may be attributable to the effects of animal group and lactation stage.

The lactose content of goat milk for cheese manufacture was 4.19 to 4.20%, and no significant difference was observed among the 3 levels of SCC in our study ($P > 0.05$). Ying et al. (2002) reported that the lactose content in goat milk had a negative correlation with logarithm of SPC and no correlation with SCC of goat milk. A lower concentration of lactose in high SCC milk induced from intramammary infection has been reported in sheep milk (Leitner et al., 2004), although no direct effect on cheese has been determined. The reduction of lactose content was mainly ascribed to damage of the mammary gland by intramammary infection. In this study, no visible damage in mammary glands was observed even if the SCC of goat milk was 1,450,000 cells/mL.

No significant differences were observed in CN content among 3 SCC levels (Table 1). This is in agreement with the finding in sheep milk by Rogers et al. (1989). However, Jaeggi et al. (2003) observed that CN content in sheep milk decreased with elevated SCC and reported a CN content of 3.99 and 3.72% when milk had <100,000 or >1,000,000 cells/mL, respectively. The CN:protein ratio and CN:fat ratio in milk did not differ among the 3 SCC levels because there was no significant difference in CN, fat, or protein content in the present study. Casein content, CN:protein ratio, and CN:fat ratio in milk are believed to have significant effects on cheese yield (Zeng et al., 2007).

Microbiological quality (i.e., SPC, CC, and PBC) of goat milk for cheese manufacture is also shown in Table 1. Standard plate count is one of the most commonly used measures for raw milk quality because it is an overall reflection of animal health status, sanitation efficiency, milking practices, and milk storage temperature (Hayes et al., 2001). The mean log SPC in milk of the present study was similar to the report of Zeng and Escobar (1996) (i.e., log 4.11 vs. log 3.98). Although log SPC of high SCC goat milk was significantly lower ($P < 0.05$) than that of the low SCC milk in this study, difference in log SPC among milk of 3 SCC levels would not impose a significant effect on cheese because log SPC was very low compared with the regulatory limit of grade A goat milk (i.e., 100,000 cfu/mL; PMO, 2007). In addition, Ying et al. (2002) pointed out that SCC did not have a positive correlation with SPC and that SCC and SPC were not equally interchangeable parameters

**Table 2.** Somatic cell count levels[1] of goat milk on cheese yield, composition, and other parameters[2,3]

| Item | Low | Medium | High | SEM |
|---|---|---|---|---|
| $Y_A$ (g/kg) | 90.61 | 91.39 | 89.82 | 1.94 |
| Moisture (%) | 48.49 | 48.96 | 49.06 | 0.59 |
| Fat in DM (%) | 45.99 | 46.28 | 45.02 | 1.38 |
| Protein in DM (%) | 46.43 | 46.25 | 45.79 | 0.64 |
| Fat (%) | 23.77 | 23.77 | 23.01 | 0.65 |
| Protein (%) | 23.84 | 23.26 | 23.26 | 0.42 |
| MNFS[4] (%) | 63.55 | 64.19 | 63.66 | 1.05 |
| $Y_{MA}$ (g/kg) | 83.62 | 83.42 | 81.68 | 1.61 |
| $Y_{DM}$ (g/kg) | 48.46 | 48.28 | 47.70 | 1.73 |
| Fat recovery (%) | 83.75 | 84.63 | 83.03 | 1.42 |
| Protein recovery (%) | 76.78 | 76.05 | 75.26 | 1.02 |
| pH | 5.34 | 5.28 | 5.30 | 0.06 |

[1]SCC levels: low = <500,000 cells/mL; medium = 500,000–1,000,000 cells/mL; high = 1,000,000–1,500,000 cells/mL.

[2]Moisture-adjusted cheese yields ($Y_{MA}$) were calculated from actual yields ($Y_A$) based on the formula $Y_{MA} = Y_A \times (100 - \text{moisture})/(100 - \text{average moisture})$.

[3]Cheese yield in DM ($Y_{DM}$) was calculated as $Y_{DM} = Y_A \times (100 - \text{moisture})/100$.

[4]MNFS = moisture in the nonfat solids.

as indicators of mammary gland infection in Alpine goats. Similarly, Park and Humphrey (1986) found no significant relationship between goat milk SCC and its SPC. There were no significant differences ($P > 0.05$) in CC and PBC among the low, medium, and high SCC groups. The results of CC were similar to that of Park (1991). A recent study in sheep milk by Vianna et al. (2008) showed that cheese made with high SCC milk exhibited a lower PBC, and the authors ascribed it to the higher activity of antimicrobial substances. Because the psychrotrophic bacteria and coliform in raw milk originated from contamination, their growth in cheese may vary with the different levels of milk SCC.

### *Effects of SCC on Cheese Yield and Composition*

Means of both actual and moisture-adjusted cheese yields are displayed in Table 2. There were no significant differences in cheese yields among the 3 SCC levels. These results are similar to those of hard cheese of sheep milk reported by Mazal et al. (2007). Klei et al. (1998) also found that SCC had no significant effect on moisture-adjusted yield of the curd. However, different findings were reported in other studies (Barbano et al., 1991; Rogers and Mitchell, 1994), which showed significantly lower cheese yields and a significantly lower protein recovery in cheese with increased SCC in cow milk. Leitner et al. (2004) found that, owing to the finding of lower CN in milk, curd yield was lower in the infected halves than in the uninfected halves. A negative correlation between SCC in milk and yield of a soft cheese was reported in dairy goats (Galina et al., 1996). Total solids of goat milk is considered the strongest indicator of yield in hard, semisoft, and soft cheeses, followed by fat and protein (Zeng et al., 2007). Factors influencing cheese yield include milk composition, amount and genetic variants of CN, SCC in milk, milk pasteurization, coagulant type, curd firmness at cutting, and manufacturing parameters (Fenelon and Guinee, 1999). In the present study, SCC was not shown to have a significant effect on TS, fat, or protein content of goat milk (Table 1) and consequently cheese yield.

Cheese pH did not vary significantly as milk SCC changed, which was in agreement with the results of Jaeggi et al. (2003) in sheep milk cheese. In contrast, Albenzio et al. (2004) indicated that high SCC resulted in higher pH in sheep milk and lower fat content in cheese curd.

With comparable CN:fat ratios from the 3 levels of SCC in sheep milk, the recovery of fat and protein from milk in the forms of cheese and whey was also comparable (Jaeggi et al., 2008). In our study, 3 levels of SCC in goat milk did not affect the recovery of fat and protein in the forms of semisoft goat cheese. However, the protein recovery values were slightly higher than those of uncooked semisoft sheep milk cheese reported by Jaeggi et al. (2005) (75.26–76.78% vs. 73.02–75.25%). These might be caused by the difference in milk type and cheese manufacturing procedure (washed and cooked goat milk cheese vs. uncooked ovine milk cheese).

### *Texture Profile and Sensory Quality of Cheese*

The effect of SCC on texture profiles of semisoft cheese is shown in Table 3. Fresh cheeses (d 1) made with low SCC goat milk showed a higher ($P < 0.05$) hardness than those made with medium and high SCC milk. Fresh cheeses made of high SCC milk had higher

**Table 3.** Somatic cell count levels[1] of goat milk on texture profiles of semisoft goat cheese at different aging stages

| | Aging stage (1 d) | | | | Aging stage (60 d) | | | | Aging stage (120 d) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Item | Low | Medium | High | SEM | Low | Medium | High | SEM | Low | Medium | High | SEM |
| Hardness (N) | 34.397[a] | 27.269[b] | 26.174[b] | 1.64 | 31.235[a] | 26.582[b] | 29.936[a] | 1.39 | 26.860[a] | 23.505[b] | 27.032[a] | 1.51 |
| Springiness (mm) | 6.193[b] | 5.435[b] | 8.045[a] | 0.68 | 7.461[a] | 7.644[a] | 6.522[b] | 0.16 | 8.630[a] | 8.467[a] | 7.904[b] | 0.19 |
| Cohesiveness (ratio) | 0.363[b] | 0.369[b] | 0.894[a] | 0.09 | 0.450 | 0.456 | 0.414 | 0.08 | 0.613 | 0.577 | 0.582 | 0.27 |
| Chewiness (N × mm) | 52.330[a] | 51.847[a] | 45.755[b] | 1.79 | 58.931[a] | 51.947[b] | 51.487[b] | 1.62 | 66.473 | 63.753 | 65.783 | 1.96 |
| Adhesiveness (J × $10^{-3}$) | −1.026[ab] | −1.089[b] | −0.758[a] | 0.09 | −0.964 | −0.943 | −0.934 | 0.09 | −0.531 | −0.567 | −0.623 | 0.14 |

[a,b]Means (n = 30; 2 × 3 × 5) in the same row within the same aging stage with different superscripts differ ($P < 0.05$) according to LSD.

[1]SCC levels: low = <500,000 cells/mL; medium = 500,000–1,000,000 cells/mL; high = 1,000,000–1,500,000 cells/mL.

($P < 0.05$) springiness and cohesiveness than those made of medium and low SCC milk. However, after 120 d of aging, cheeses made with low SCC milk showed lower hardness and higher springiness than those made with high SCC milk. Various results on the effect of SCC on hardness of cheese have been reported in several studies. Whereas some earlier studies (Rogers and Mitchell, 1994) reported a decrease in hardness with increased SCC in a sensory test, a recent study by Mazal et al. (2007) did not demonstrate lower firmness of cheese resulting from higher SCC milk.

As illustrated in Table 4, the hardness of all cheeses decreased significantly ($P < 0.05$) and the springiness increased as cheese aging advanced. Hardness of TPA is the maximum force during the first compression cycle, springiness is the height the sample recovers between the first and second compressions, and cohesiveness is the ratio of the positive force area of the second compression to that of the first (Tunick, 2000). Cheeses aged for 120 d showed higher cohesiveness and chewiness scores than did fresh cheese ($P < 0.05$). The hardness and chewiness score of cheeses at ripening d 60 were not different ($P > 0.05$) from those at d 120. This observation indicated that cheese aged for 60 d should be ready for consumption because aging after d 60 did not improve body and texture. Cheese is a complex, multiphase, multicomponent colloidal system. The response of the cheese to external forces can reveal structural features directly related to texture (Bhaskaracharya, 1998). Most of the cheeses became less hard and less cohesive with increasing age, and the values for chewiness usually decreased with storage (Tunick and Van Hekken, 2000).

Effects of SCC levels in goat milk on flavor, body, and texture and total sensory scores of semisoft fresh cheese are shown in Figure 1. Cheeses made of low and medium SCC milk did not differ in body and texture score ($P > 0.05$); both had a higher body and texture score than did cheese made of high SCC milk (Figure 1A), indicating that high SCC in milk could affect the body and texture score of fresh cheeses. The effect of SCC on total sensory score was similar to that of body and texture (Figure 1C). Vianna et al. (2008) also found that the overall acceptance of Proto cheese (a semisoft cheese) was significantly affected by cow milk SCC. Milk with high SCC is associated with a low overall appreciation and with texture and flavor defects in the cheese (Auldist and Hubble, 1998). The sensory quality of cheese depends on several factors linked to both the cheesemaking technology and the microbiological characteristics of raw milk (Coulon et al., 2004). Any changes in the composition will result in different structural arrangements and different textural characteristics (Bryant et al., 1995). No difference in flavor score was detected among cheeses made of milk with different levels of SCC ($P > 0.05$; Figure 1B), which is in agreement with the results of Jaeggi et al. (2003). In their study, it was observed that there were no differences in either scores of flavor and body and texture in 1- and 3-mo-old hard cheeses of sheep milk.

There was no significant difference in flavor and total sensory scores between ripened cheese at d 60 and 120

**Table 4.** Effect of aging on the texture profile of semisoft goat cheese

| Item | Fresh cheese (d 1) | Aged cheese (d 60) | Aged cheese (d 120) |
|---|---|---|---|
| Hardness (N) | 30.508 ± 1.494[a] | 29.588 ± 1.494[ab] | 25.713 ± 1.494[c] |
| Springiness (mm) | 6.043 ± 0.207[c] | 6.957 ± 0.2073[b] | 8.098 ± 0.207[a] |
| Cohesiveness (ratio) | 0.406 ± 0.028[b] | 0.435 ± 0.028[b] | 0.594 ± 0.028[a] |
| Chewiness (N × mm) | 10.804 ± 0.796[b] | 12.741 ± 0.796[ab] | 14.834 ± 0.796[a] |
| Adhesiveness (J × $10^{-3}$) | −0.0010 ± 0.0001 | −0.0010 ± 0.0001 | −0.0007 ± 0.0001 |

[a–c]Means (n = 90; 2 × 3 × 5 × 3) in the same row with different superscripts differ ($P < 0.05$) according to LSD.

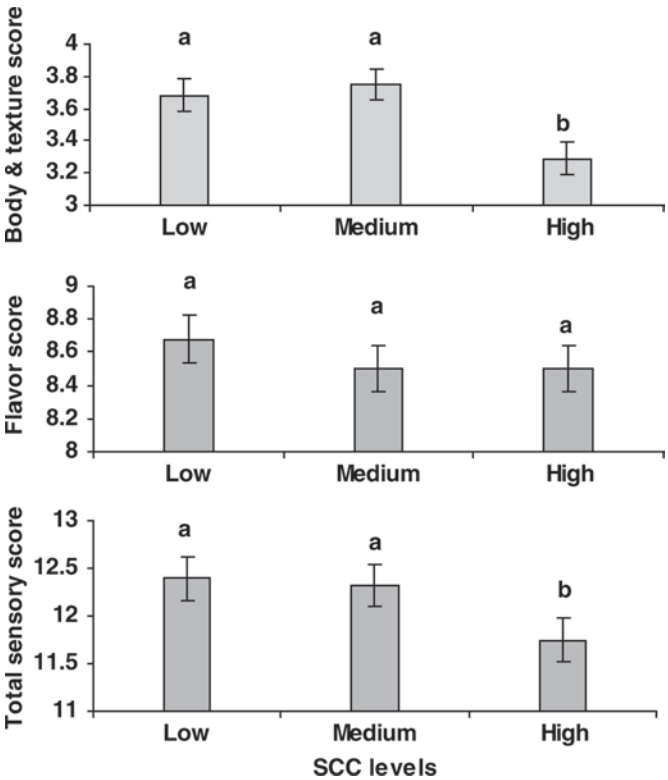


**Figure 1.** Effect of SCC levels in goat milk on flavor, texture, and total sensory scores of semisoft goat cheese (fresh and 60 and 120 d aged). Means (n = 54; 2 × 3 × 3 × 3) with different letters differ ($P < 0.05$) according to LSD.

(Figure 2B,C), indicating that this semisoft goat cheese could be appropriately marketed and consumed at d 60. The cheese did not benefit from further ripening beyond 60 d and yet did not deteriorate in either flavor or total sensory scores within 120 d.

### FFA Profile of Cheeses

The effect of SCC on fatty acid profile of cheeses during ripening is shown in Table 5. The mean fatty acid composition of cheeses made with goat milk with low, medium, and high SCC levels did not exhibit significant differences at the beginning and d 60 of ripening. After 120 d of ripening, however, cheese made with low SCC milk had a higher ($P > 0.05$) total FFA than that made with medium and high SCC milk. The milk SCC level did not have a significant effect on total FFA of cheeses at d 60, which is in agreement with the results of pasteurized goat milk cheese reported by Buffa et al. (2001) and hard ewe milk cheese by Jaeggi et al. (2003). In cheese, lipid hydrolysis results in the formation of FFA, especially those short- and intermediate-chain FFA that may contribute to cheese flavor and also serve as substrates for further reactions, producing highly flavored catabolic end products (Collins et al., 2003).

The predominant FFA observed in the fresh cheeses were saturated long-chain palmitic acid (C16:0) and stearic acid (C18:0), representing 35.53 and 14.93% of the total FFA, respectively, and unsaturated long-chain oleic acid (C18:1), accounting for 23.52% of the total FFA (Table 6). The percentage of total unsaturated FFA in total FFA of cheese was 26.56%. Similarly, Soryal et al. (2003) reported that total unsaturated fatty acids represented 26.83% of total fatty acids in goat milk. Short-chain FFA accounted for only 3.00% of the total FFA. The profiles of FFA in goat milk cheese were different from those in sheep milk cheese as reported by Jaeggi et al. (2003). The most abundant FFA in sheep cheeses of all 3 SCC levels was palmitic acid (30–32% of total FFA), and short-chain FFA composed 17 to 22%. Woo et al. (1984) reported that Colby cheese contained relatively low concentrations of FFA, whereas cheese manufactured with goat milk had higher caprylic acid and capric acid concentration and strong goaty flavor. Increased lipolytic activities in the milk with the highest SCC may have contributed to great lipolysis (Jaeggi et al., 2003). In the present study, the semisoft goat milk cheese might have demonstrated the difference in

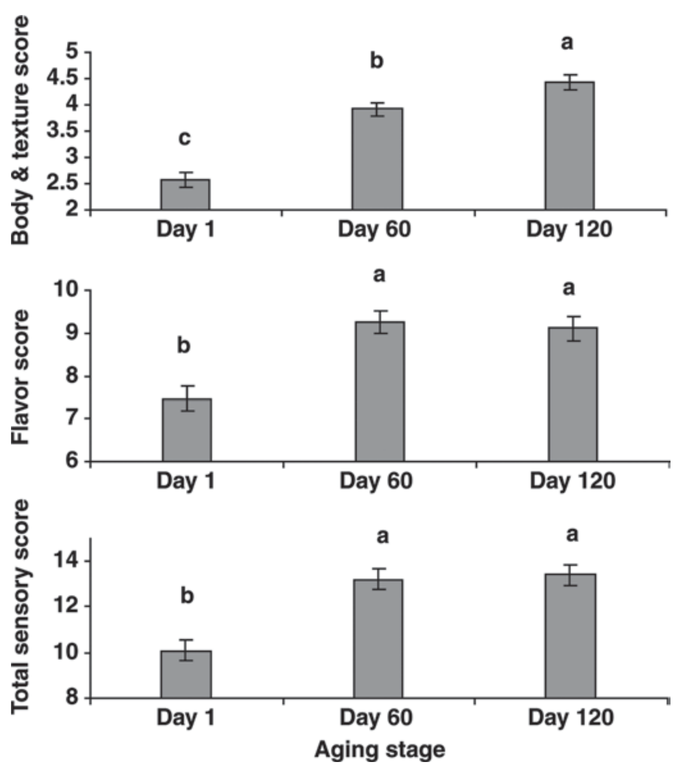


**Figure 2.** Effects of aging on the flavor, texture, and total scores of semisoft goat cheese. Means (n = 54; 2 × 3 × 3 × 3) with different letters differ ($P < 0.05$) according to LSD.

**Table 5.** Somatic cell count levels[1] of goat milk on free fatty acids (FFA) profile of semisoft goat cheese at different aging stages

| Item | Aging stage (1 d) | | | | Aging stage (60 d) | | | | Aging stage (120 d) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Low | Medium | High | SEM | Low | Medium | High | SEM | Low | Medium | High | SEM |
| FFA (g/L) | | | | | | | | | | | | |
| Butyric acid (C4:0) | 0.098 | 0.115 | 0.116 | 0.107 | 0.358 | 0.304 | 0.340 | 0.103 | 0.535 | 0.534 | 0.499 | 0.103 |
| Caproic acid (C6:0) | 0.216 | 0.192 | 0.209 | 0.019 | 0.135 | 0.144 | 0.144 | 0.015 | 0.123[a] | 0.139[a] | 0.169[b] | 0.015 |
| Caprylic acid (C8:0) | 0.106 | 0.102 | 0.122 | 0.106 | 0.327 | 0.287 | 0.315 | 0.097 | 0.508 | 0.565 | 0.486 | 0.097 |
| Capric acid (C10:0) | 0.625 | 0.657 | 0.709 | 0.271 | 1.166 | 1.102 | 1.117 | 0.262 | 1.608 | 1.806 | 1.806 | 0.262 |
| Lauric acid (C12:0) | 0.688 | 0.705 | 0.755 | 0.141 | 1.259 | 1.294 | 1.234 | 0.136 | 1.627 | 1.545 | 1.492 | 0.136 |
| Myristic acid (C14:0) | 1.212 | 1.201 | 1.323 | 0.230 | 1.657 | 1.671 | 1.669 | 0.224 | 1.852 | 1.963 | 1.828 | 0.224 |
| Palmitic acid (C16:0) | 4.693 | 4.405 | 5.096 | 0.452 | 5.498 | 5.435 | 5.346 | 0.457 | 5.605 | 4.901 | 5.618 | 0.457 |
| Palmitoleic acid (C16:1) | 0.186 | 0.197 | 0.194 | 0.049 | 0.331 | 0.317 | 0.304 | 0.046 | 5.096 | 0.418 | 0.375 | 0.046 |
| Stearic acid (C18:0) | 1.798 | 1.635 | 2.493 | 0.323 | 2.395 | 2.393 | 2.314 | 0.319 | 2.546 | 2.728 | 2.897 | 0.319 |
| Oleic acid (C18:1) | 3.144 | 2.855 | 3.361 | 0.577 | 4.849 | 4.913 | 4.811 | 0.574 | 5.250 | 5.775 | 5.565 | 0.574 |
| Linoleic acid (C18:2) | 0.209 | 0.207 | 0.213 | 0.082 | 0.485 | 0.508 | 0.483 | 0.077 | 0.562 | 0.629 | 0.577 | 0.077 |
| Linolenic acid (C18:3) | ND[2] | ND | ND | 0.041 | 0.112 | 0.081 | 0.087 | 0.038 | 0.154 | 0.165 | 0.110 | 0.038 |
| Arachic acid (C20:0) | 0.044 | 0.022 | 0.054 | 0.079 | 0.282 | 0.355 | 0.261 | 0.076 | 0.301 | 0.328 | 0.286 | 0.076 |
| Total FFA | 13.003 | 12.260 | 14.643 | 0.190 | 18.851 | 18.804 | 18.425 | 0.188 | 21.086 | 19.730 | 20.707 | 0.188 |
| Summary | | | | | | | | | | | | |
| Short-chain (C4–C8) | 0.406 | 0.374 | 0.446 | 0.191 | 0.819 | 0.735 | 0.799 | 0.187 | 1.165 | 1.237 | 1.154 | 0.187 |
| Medium-chain (C10–C14) | 2.525 | 2.563 | 2.787 | 0.339 | 4.082 | 4.07 | 4.02 | 0.461 | 5.087 | 5.314 | 5.126 | 0.525 |
| Long-chain (>C16) | 10.072 | 9.323 | 11.41 | 0.196 | 13.950 | 13.999 | 13.606 | 0.193 | 14.834 | 13.179 | 14.427 | 0.216 |

[a,b]Means (n = 12; 2 × 3 × 2) in the same row within the same aging stage with different superscripts differ ($P < 0.05$) according to LSD.

[1]SCC levels: low = <500,000 cells/mL; medium = 500,000–1,000,000 cells/mL; high = 1,000,000–1,500,000 cells/mL.

[2]ND = not detectable.

FFA profiles with other studies, probably because of different animal species and cheese variety.

As cheese aged, total FFA content increased significantly ($P < 0.05$; Table 6). The percentage of short-chain FFA increased significantly from 3.08% (fresh cheese) to 5.78% (aged cheese of 120 d). The butyric content increased from 0.82% in fresh cheese to 2.55% in aged cheese at d 120 ($P < 0.05$). For the great majority of cheeses, the amount of all individual FFA increased during ripening (Chávarri et al., 1999). Pavia et al. (2000) reported that total FFA in Manchego cheese was correlated with age during the 3-mo ripening period, whereas Jaeggi et al. (2003) found that the total FFA did not change significantly in sheep milk hard cheese in the first 6 mo of aging. Ponce de Leon-Gonzalez et al. (2002) also reported that the concentration of FFA did not increase significantly during ripening in

**Table 6.** Effects of aging on free fatty acids (FFA) profile of semisoft goat cheese

| Item | Fresh cheese (d 1) | Aged cheese (d 60) | Aged cheese (d 120) |
|---|---|---|---|
| FFA (mg/g of fat) | | | |
| Butyric acid (C4:0) | 0.109 ± 0.063[c] | 0.334 ± 0.057[b] | 0.523 ± 0.057[a] |
| Caproic acid (C6:0) | 0.206 ± 0.008[a] | 0.141 ± 0.008[b] | 0.144 ± 0.008[b] |
| Caprylic acid (C8:0) | 0.111 ± 0.055[c] | 0.309 ± 0.054[b] | 0.519 ± 0.054[a] |
| Capric acid (C10:0) | 0.666 ± 0.150[c] | 1.128 ± 0.145[b] | 1.675 ± 0.145[a] |
| Lauric acid (C12:0) | 0.716 ± 0.078[c] | 1.263 ± 0.075[b] | 1.555 ± 0.075[a] |
| Myristic acid (C14:0) | 1.249 ± 0.128[b] | 1.665 ± 0.124[a] | 1.881 ± 0.124[a] |
| Palmitic acid (C16:0) | 4.737 ± 0.263[a] | 5.426 ± 0.255[a] | 5.401 ± 0.280[a] |
| Palmitoleic acid (C16:1) | 0.192 ± 0.026[c] | 0.317 ± 0.026[b] | 0.403 ± 0.026[a] |
| Stearic acid (C18:0) | 1.990 ± 0.186[b] | 2.367 ± 0.181[ab] | 2.724 ± 0.181[a] |
| Oleic acid (C18:1) | 3.137 ± 0.329[b] | 4.858 ± 0.319[a] | 5.530 ± 0.319[a] |
| Linoleic acid (C18:2) | 0.210 ± 0.044[b] | 0.492 ± 0.043[a] | 0.589 ± 0.043[a] |
| Linolenic acid (C18:3) | 0.002 ± 0.021[b] | 0.093 ± 0.021[a] | 0.143 ± 0.021[a] |
| Arachic acid (C20:0) | 0.042 ± 0.043[b] | 0.299 ± 0.042[a] | 0.305 ± 0.042[a] |
| Total FFA | 13.332 ± 1.107[b] | 18.693 ± 1.073[b] | 20.507 ± 1.073[a] |
| Summary | | | |
| Short-chain (C4–C8) | 0.410 ± 0.107[c] | 0.784 ± 0.104[b] | 1.186 ± 0.104[a] |
| Middle-chain (C10–C14) | 2.625 ± 0.312[c] | 4.057 ± 0.467[b] | 5.175 ± 0.459[a] |
| Long-chain (>C16) | 10.268 ± 0.194[b] | 13.852 ± 0.189[a] | 14.147 ± 0.278[a] |

[a–c]Means (n = 36; 2 × 3 × 2 × 3) in the same row with different superscripts differed ($P < 0.05$) according to LSD.

reduced-fat Muenster-type cheese made from a mixture of cow skim milk and sheep whole milk.

## CONCLUSIONS

Somatic cell count levels in goat milk below the legal limit did not affect milk composition (fat, protein, TS, and so on) and thus did not affect semisoft cheese yield. At the beginning of ripening, there was no difference in cheese flavor score among the SCC levels. However, high SCC milk resulted in a lower texture score and thus a lower total sensory score. Sensory scores indicated that goat milk semisoft cheese aged for 60 d is ready for the market and consumption. The change of FFA indicated that cheese made with high SCC milk had higher lipolysis during ripening than that made with low SCC milk. However, further investigation is needed to determine the effect of SCC on the protein hydrolysis of goat milk semisoft cheese.

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